BRIEFER ARTICLES

THE NUMBER AND SIZE OF THE STOMATA

For some educational purposes it is needful to know which plants possess the largest, the most numerous, the most readily observable, or the most definitely distributed stomata, and what quantities are involved in each of these features. The most important work upon the subject thus far is by WEISS,[1] but he includes only a few of those plants used for laboratory study in this country, namely, the common greenhouse plants and those readily raised in greenhouses from seed. Accordingly, in continuation of similar studies upon other topics as already described in this journal,[2] I have undertaken to obtain exact data upon this subject, with results recorded below. The study was begun, and carried well along, by Miss ALICE T. MITCHELL, while a senior student in Smith College, but she was unable to bring it into final form. I undertook at first simply to complete her work, but later I found it better, in order that all the results might represent a single method of treatment, to work over the entire subject from the beginning. The work has been done in the laboratory of plant physiology in Smith College, and has had the criticism and advice of Professor W. F. GANONG.

My method of study, in general, was that developed by LLOYD in his recent investigations[3] on the stomata of desert plants. I removed pieces of the epidermis from different parts of full-grown representative leaves, and dropped the pieces immediately into absolute alcohol. In order to test the possible effect of any shrinkage of the epidermis upon the numerical results, I made many comparisons of the data yielded by the epidermis alone with those yielded by untreated leaves; but I found no appreciable differences. I used throughout the same microscope and combination (Zeiss, objective DD, ocular 1 with cross hairs as an aid to counting). In counting the stomata, I adopted WEISS's method of counting all those falling within the field of vision, the area of which is easily calculated and reduced to square millimeters. For every species I counted the stomata, and calculated the mean, from thirty different fields selected at random from epidermis taken from three different plants (or, in two cases only, from different

[1] Jahrb. Wiss. Bot. 4:123, 196. 1865–1866.

[2] BOT. GAZETTE 40:302. 1905; 45:50. 1908; 45:254. 1908; 46:50. 1908.

[3] LLOYD, F. E., The physiology of stomata. Publ. Carnegie Institution. 1908.

shoots of the same plant), this precaution being observed in order to minimize any possible abnormalities of single plants.

In order to measure the size of the stomata, which involves the length and breadth of the guard cell apparatus when closed, and the length and breadth of the pore when most widely open, the same general method was used, except that, in order to prevent the closure of the pore through any possible wilting of the leaf, the epidermis was removed while the leaves were still attached to the plants. The pores of the stomata were found as a rule to be widest open at about 10 A. M., and accordingly the material was taken at that time. The measurements were made with an ocular micrometer, carefully valued by comparison with a stage micrometer. As in the case of the countings, thirty measurements were made upon material practically taken at random from three plants, and the figures in the table represent the mean of these. Only the linear dimensions of the pore are given in the table, but the area can very easily be determined by treating the opening as an ellipse,[4] though it is to be remembered, as BROWN and ESCOMB have shown,[5] that in the passage of gases through stomata, it is the linear dimensions, and not the area, which is important.

The data of the accompanying table may be summarized as follows. The stomata of our common greenhouse plants occur chiefly upon the under surfaces of the leaves, only about two-fifths (43 per cent.) having any upon the upper surface, and those almost invariably far less numerous than those upon the under. The most numerous stomata occur (in order of abundance) in Abutilon, *Ficus repens*, *Phaseolus vulgaris*, *Cucurbita Pepo*, and *Salvia involucrata*. The largest occur (in order of size) in *Triticum sativum*, Tulipa, *Avena sativa*, *Primula sinensis*, *Chrysanthemum frutescens*, and *Tradescantia zebrina*. In a general way, there is an inverse proportion between number and size of stomata. Taking all of the plants collectively, the number of stomata ranges from 0 through a mean of 121 to 484 per square millimeter, or, in general terms, they average over 100 to the square millimeter. The mean size of the open pores is $17.7 \times 6.7\ \mu$, and the mean area is 92 square μ. The total pore area for a square millimeter of leaf, therefore, is 11,132 square μ (121×92), which means that when the pores are open, one-ninetieth (or in round numbers over one-hundredth) of the epidermal surface is open.

Some other points worthy of mention in connection with the practical study of stomata in the laboratory are the following:

4 Area of an ellipse $= \frac{\text{length}}{2} \times \frac{\text{breadth}}{2} \times \pi$.

5 Nature **62**:212.

The epidermis may readily be stripped in large pieces from the majority of greenhouse plants, notably from *Chrysanthemum frutescens*, *Cyclamen latifolium*, *Pelargonium zonale*, *Helianthus annuus*, Tulipa, *Vicia Faba*, and *Tradescantia zebrina*. It can be removed, though with difficulty, from some others, such as Abutilon, *Cestrum elegans*, and *Coleus Blumei*, while in some, e. g., *Ficus elastica* and *Hedera Helix*, it can be removed only by tangential sectioning with a razor.

STOMATA-QUANTITIES IN GREENHOUSE PLANTS

	NUMBER Minimum, mean, maximum in 1 square millimeter		SIZE Length and breadth in microns			
	Upper surface	Lower surface	Upper surface		Lower surface	
			Guard cells closed	Pore open	Guard cells closed	Pore open
Abutilon	0	198–**333**–484	0	0	17×15	6×3
Avena sativa	13–**25**–39	13–**23**–30	64×32	31×7	70×36	38×8
Begonia coccinea	0	22–**40**–53	0	0	42×29	21×8
Cestrum elegans	0	92–**146**–224	0	0	34×25	14×7
Chrysanthemum frutescens	4–**15**–35	22–**34**–61	57×31	31×11	58×31	33×11
Cineraria cruenta	0	39–**55**–88	0	0	40×27	25×8
Coleus Blumei	0	105–**141**–211	0	0	24×19	10×5
Cucurbita Pepo	6–**28**–68	175–**269**–368	21×14	5×2	20×16	6×3
Cyclamen latifolium	0	44–**68**–96	0	0	45×33	21×7
Euphorbia pulcherrima	0	176–**233**–365	0	0	26×19	11×7
Fagopyrum esculentum	17–**45**–66	127–**152**–184	27×20	10×5	27×21	12×6
Ficus elastica	0	83–**117**–180	0	0	40×36	19×6
Ficus repens	0	228–**282**–365	0	0	21×17	5×3
Fuchsia speciosa	0	52–**121**–193	0	0	39×28	19×7
Hedera Helix	0	123–**158**–193	0	0	29×26	11×4
Helianthus annuus	52–**85**–118	96–**156**–268	33×21	18×8	36×21	22×8
Heliotropium peruvianum	0	118–**149**–176	0	0	21×17	9×5
Impatiens Sultani	0	118–**208**–396	0	0	26×18	9×6
Lycopersicum esculentum	0–**12**–87	79–**130**–202	27×20	10×5	33×23	13×6
Oxalis Bowiei	0	52–**77**–118	0	0	28×21	11×4
Pelargonium domesticum	8–**19**–35	39–**59**–88	47×34	23×8	45×32	24×9
Pelargonium peltatum	4–**11**–22	13–**28**–48	46×31	20×6	45×30	22×7
Pelargonium zonale	8–**22**–39	83–**118**–171	37×26	16×9	37×25	19×12
Phaseolus vulgaris	13–**40**–96	184–**281**–356	25×14	8×3	21×13	7×3
Primula obconica	0	26–**47**–70	0	0	39×34	17×6
Primula sinensis	0	22–**31**–48	0	0	59×46	30×9
Ricinus communis	39–**64**–96	140–**176**–224	30×16	8×4	30×20	10×4
Salvia involucrata	0	211–**263**–330	0	0	20×16	9×3
Senecio mikanioides	0	83–**114**–158	0	0	30×24	10×7
Senecio Petasitis	0	66–**106**–149	0	0	44×32	23×10
Tradescantia zebrina	0	8–**14**–22	0	0	55×33	31×12
Triticum sativum	22–**33**–44	8–**14**–26	79×37	40×7	84×35	38×7
Tropaeolum majus	0	92–**130**–171	0	0	27×17	12×6
Tulipa hybrid	22–**40**–57	35–**47**–66	56×35	18×7	72×35	32×10
Vicia Faba	35–**48**–66	39–**52**–70	44×27	19×8	46×28	20×8
Vicia Faba equina	17–**34**–52	30–**48**–61	42×26	18×8	43×28	19×8
Zea Mais	39–**52**–79	52–**68**–88	47×36	19×4	45×36	19×5

Counting or measuring the stomata *in situ* on the leaf is possible with a few plants, notably *Begonia coccinea*, *Chrysanthemum frutescens*, *Fuchsia speciosa*, *Impatiens Sultani*, *Primula obconica*, *Pelargonium zonale*, *Tradescantia zebrina*, and *Vicia Faba*. In some others the condition of the pore can thus be observed, though the outlines of the guard cells are not clear: this is true in *Senecio Petasitis*, *Helianthus annuus*, *Cyclamen latifolium*, *Coleus Blumei*, *Cestrum elegans*, and *Phaseolus vulgaris*.

Marked variations in number and size of stomata occur, not only in different varieties of the same species, but in the same varieties grown under different external conditions. So far as my observation goes, however, the variation is greater in number than in size. Furthermore, while in most leaves the stomata are fairly evenly distributed over the surfaces containing them, in some, especially in oblong leaves (e. g., *Fuchsia speciosa*, *Helianthus annuus*, and *Impatiens Sultani*), the stomata are much more numerous near the base than near the tip (more than twice as many), and near the midrib than near the margin. For this reason very different figures might be given for the same leaf by different observers.

The opening and closing of the stomata of greenhouse plants is correlated closely with the time of day, and secondarily with the weather. As already noted, they are, as a rule, as wide open as they can be about 10 A. M. —this, of course, in well-watered plants. In favorable weather they remain wide open until about 2.30 P. M., when they begin to close, and they are mostly completely closed by 5 P. M., though some may remain open until 6. On hot days in the spring they may close as early as 12 M., probably because of incipient wilting of the leaf. If the stomata are closed by wilting, they may be made to open, partially at least, by immersion of the leaf in water.

The best plants for general laboratory study, taking account of ease of removing the epidermis, size and clearness of stomata, and commonness of occurrence in greenhouses, are, in order of excellence, *Chrysanthemum frutescens*, *Tradescantia zebrina*, *Pelargonium zonale*, *Fuchsia speciosa*, *Helianthus annuus*, and *Vicia Faba*.—SOPHIA H. ECKERSON, *Smith College, Northampton, Mass.*

THE ABSORPTIVE POWER OF A CULTIVATED SOIL

(WITH THREE FIGURES)

In the winter of 1908 we undertook a study of the absorptive power of a certain soil from one of the fields of the Michigan Agricultural College. In addition to the purely analytical methods which have been exclusively employed up to the present time in investigations of this kind, it was decided